APPENDIX A

MIXER TRANSFER PROPERTIES

INTRODUCTION

The RF to IF conversion of received signals in radars is accomplished by the radar mixer which mixes the stable local oscillator (STALO) output signal with the amplified RF received signal. Figure A-1 shows a simplified block diagram of a radar mixer. The following is a discussion of the Noise, Signal-to-Noise (SNR), and Interference-to-Noise (INR) transfer properties of a typical radar mixer.

MIXER TRANSFER PROPERTIES

The radar STALO signal time waveform, $v_s(t)$, can be expressed as:

$$v_s(t) = \cos\,[(\omega_o + \beta_o)t + \phi_s] \qquad \text{(A-1)}$$

where:

β_o = Receiver tuned IF frequency, in radians per second

ϕ_s = Phase of STALO signal

Assuming linear transfer properties for a radar mixer, the noise and signal can be treated separately.

Noise

To calculate N_{mi} and N_{mo}, the noise power at the input and output of the mixer, the bandpass noise model is used, and the mixer input noise signal, $n_{mi}(t)$, is given by:

$$n_{mi}(t) = n_c(t)\cos\omega_o t + n_s(t)\sin\omega_o t \qquad \text{(A-2)}$$

Where $n_{mi}(t)$ is the RF bandpass noise at the input of the mixer, and the mixer input noise power (mean square of $n_{mi}(t)$ is given by:

$$N_{mi} = \overline{n_{mi}^2(t)} \qquad \text{(A-3)}$$

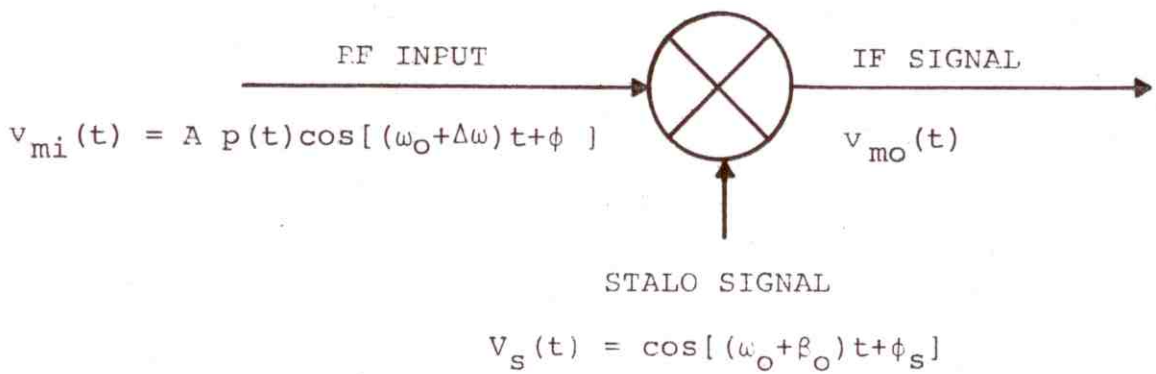

Figure A-1. Radar Mixer Block Diagram

Generally, the STALO signal power level is greater than 0 dBm. Therefore, the mixer noise figure (conversion loss) is very small and can be neglected. Also, the STALO signal is usually filtered and the noise suppressed, thus permitting the STALO signal noise level to be neglected.

If $n_{mi}(t)$ is applied at the input of the mixer (which multiplies the incoming noise signal, $n_{mi}(t)$ by $v_s(t)$, then $n_{mo}(t)$, the output noise of the mixer, is given by:

$$n_{mo}(t) = n_c(t) \cos \omega_o t \cdot \cos [(\omega_o + \beta_o)t + \phi_s] + n_s(t) \sin \omega_o t \cdot \cos [(\omega_o + \beta_o)t + \phi_s] \quad \text{(A-4a)}$$

$$= \frac{n_c(t)}{2} [\cos[(2\omega_o + \beta_o)t + \phi_s] + \cos [\beta_o t + \phi_s]] + \frac{n_s(t)}{2} [\sin[(2\omega_o + \beta_o)t + \phi_s] - \sin[\beta_o t + \phi_s]] \quad \text{(A-4b)}$$

The terms $\cos [(2\omega_o+\beta_o)t+\phi_s]$ and $\sin [(2\omega_o+\beta_o)t+\phi_s]$ represents the spectra of $n_c(t)$ and $n_s(t)$, respectively, shifted at $(2\omega_o + \beta_o)$ and are filtered out by the IF filter at the mixer output. Hence, $n_{mo}(t)$ is given by:

$$n_{mo}(t) = \frac{n_c(t)}{2} \cos (\beta_o t + \phi_s) - \frac{n_s(t)}{2} \sin (\beta_o t + \phi_s) \quad \text{(A-5)}$$

The mixer output noise power (mean square of $n_{mo}(t)$ can be related to the mixer input noise power, Equation A-3, and the mixer noise power transfer properties expressed as:

$$N_{mo} = \overline{n_{mo}^2(t)} = \overline{\tfrac{1}{4}\, n_{mi}^2(t)} \quad \text{(A-6a)}$$

$$= \tfrac{1}{4} N_{mi} \quad \text{(A-6b)}$$

Desired/Interfering Signal

The desired and interfering signal voltage waveform at the mixer input, $v_{mi}(t)$, can be expressed as:

$$v_{mi}(t) = Ap(t) \cos [(\omega_o + \Delta\omega)t + \phi] \quad \text{(A-7)}$$

where:

A = Signal voltage amplitude

$p(t)$ = Signal amplitude modulation, value between 0 and 1

ω_o = Receiver tuned RF frequency, in radians per second

$\Delta\omega$ = Frequency separation between interfering signal carrier frequency and receiver tuned frequency ($\Delta\omega$ = 0 for desired signal), in radians per second

ϕ = Phase of signal

Since we are only concerned with the peak power of the desired or interfering signal, p(t) equals 1, and the signal power at the input to the mixer (the mean square of $v_{mi}(t)$ is:

$$S_{mi} = \overline{v_{mi}^2(t)} = \frac{A^2}{2} \qquad \text{(A-8)}$$

The signal voltage time waveform at the mixer output, $v_{mo}(t)$, can be found by performing the operation shown in Figure A-1 and is given by:

$$v_{mo}(t) = v_{mi}(t) \cdot v_s(t) \qquad \text{(A-9a)}$$

$$= A \cos [(\omega_o + \Delta\omega)t + \phi] \cdot \cos [(\omega_o + \beta_o)t + \phi_s] \qquad \text{(A-9b)}$$

$$= \frac{A}{2} [\cos[(2\omega_o + \Delta\omega + \beta_o)t + \phi + \phi_s] \qquad \text{(A-9c)}$$

$$+ \cos [(\beta_o - \Delta\omega)t + \phi_s - \phi]]$$

The first term of Equation A-9c is filtered out by the IF filter, resulting in a signal with a frequency $(\beta_o - \Delta\omega)$ where $\Delta\omega$ = 0 for the desired signal, and a mixer output power (the mean square of $v_{mo}(t)$ of:

$$S_{mo} = \overline{v_{mo}^2(t)} = \frac{A^2}{8} \qquad \text{(A-10a)}$$

$$= \tfrac{1}{4} S_{mi} \qquad \text{(A-10b)}$$

Therefore, the signal peak power is reduced 6 dB by the mixer.

SNR Transfer Properties

Using Equations A-6b and A-10b, the mixer signal-to-noise (SNR) transfer properties of the mixer are given by:

$$SNR_{mo} = SNR_{mi} \tag{A-11}$$

Therefore, the SNR at the mixer output is equal to the SNR at the mixer input. Equation A-11 is also applicable to the interference-to-noise (INR) transfer properties of the mixer.

IMAGE RESPONSE

For the case when the interfering signal frequency separation, $\Delta\omega$, is equal to $2\beta_o$, the interfering signal frequency at the mixer output will equal the IF tuned frequency. However, in most radars in the 2.7 to 2.9 GHz band, the preselector filter attenuates the interfering signal image response by approximately 50 to 60 dB.